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1.	Your Reference	P58765V		
2.	Patent Application number *(The Patent Office will fill in this part)*	0223769.1		14 OCT 2002
3.	Full name, address and postcode of the or each applicant *(underline all surnames)*	The BOC Group plc Chertsey Road Windlesham Surrey GU20 6HJ		
	Patents ADP Number *(if you know it)*	8846270002		
	If the applicant is a corporate body, give the country/state of its incorporation	UK		
4.	Title of the invention	A PUMP		
5.	Name of your agent *(if you have one)* "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	~~Fry Heath & Spence LLP~~ ~~The Gables~~ ~~Massetts Road~~ ~~Horley, Surrey RH6 7DQ~~	THE BOC GROUP PLC CHERTSEY ROAD WINDLESHAM, SURREY, GU20 6HJ	
	Patents ADP Number *(if you know it)*	05880273001 8459554001		FSI MB 13.10
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or each of these earlier applications and *(if you know it)* the or each application number.	Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application.	Number of earlier application		Date of filing *(day / month / year)*
8.	Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* *a) any applicant named in part 3 is not an inventor; or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body.* *(See note (d))*	Yes		

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11. I/We request the grant of a patent on the basis of this application.

Signature V Townsend

Date 14 October 2002

12. Name and daytime telephone number of person to contact in the United Kingdom

Victoria J Townsend - 01293 776880

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DUPLICATE

A PUMP

This invention relates to the field of vacuum pumps. In particular thermal control of vacuum pumps with a screw type configuration.

Screw pumps usually comprise two spaced parallel shafts each carrying externally threaded rotors, the shafts being mounted in a pump body such that the threads of the rotors intermesh. Close tolerances between the rotor threads at the points of intermeshing and with the internal surface of the pump body, which acts as a stator, causes volumes of gas being pumped between an inlet and an outlet to be trapped between the threads of the rotors and the internal surface and thereby urged through the pump as the rotors rotate.

Prior art screw pumps use a water cooling jacket around sections of the machine in order to remove the heat of compression. However, the inlet of the machine does not have any cooling system since, at low pressures, there is little heat of compression to be removed from the inlet. As the pressure increases any additional heat is dispersed from the inlet by the increased gas flow through it. Where the pump is located in a cold environment, surface temperatures within the inlet of the pump may reduce significantly and form cold spots such that gaseous waste products from the evacuation chamber condense into liquid pools in these cooler regions. These pools can be formed from highly corrosive acid or base fluids and can lead to damage of the pump components, which, in turn, can reduce the life of the device.

Screw pumps are increasingly being utilised in a broad range of applications. For example within a pharmaceutical process area the same pump may be required to perform numerous different applications. Whilst the configuration of a pump may be tailored to a particular application, once the application is altered, ideal conditions will no longer be present and the pump will not be performing at peak/optimum efficiency.

It is an aim of the present invention to overcome some of the aforementioned problems associated with screw pump technology.

According to the present invention there is provided a pump comprising at least one rotor, a stator and a housing, the housing comprising an inner skin and an outer skin, a first cavity being formed by the inner skin, the rotor being mounted therein and a second cavity being formed between the inner and outer skins of the housing through which a fluid is circulated, in use, wherein, the second cavity extends the length of and encircles the rotor.

The inner skin of the housing may act as the stator, in use. The rotor of the pump may comprise one inlet portion and two exhaust portions such that the pump is a double-ended pump.

The pump may further comprise a fluid channel within either the rotor or the stator, or there may be a fluid channel located within each of these components. A thermal controller may be provided for controlling the temperature of any fluid in these channels. The thermal controller may comprise a temperature sensor, located at the stator and a further temperature sensor, located in the vicinity of the exhaust. Additionally, the thermal controller may include at least one of each of a variable speed flow pump, a thermostatic control valve and a heat exchanger.

The pump may be of any known form, for example but not strictly limited to; a screw pump, a claw pump or a roots pump.

According to the present invention there is further provided a method for releasing the rotors of a pump that have seized due to the presence of deposits of a substance which has solidified on the internal working surfaces of the pump on cooling, comprising the steps of:

introducing a thermal fluid into a cavity provided within the housing of the pump, the cavity encircling the rotor components;

heating the thermal fluid in the cavity to a predetermined temperature, this temperature being sufficiently high to cause the deposits to be softened; and

applying torque to the rotors of the pump to overcome any remaining impeding force caused by the deposits located on the internal working surfaces of the pump.

According to the present invention there is further provided a method for controlling a clearance between a rotor and stator within a pump, of the present invention, the method comprising the steps of:

(a) recording the temperature of each of the stator and the rotor from the sensors;

(b) calculating the temperature difference between the stator and the rotor;

(c) comparing the temperature difference with a predetermined value;

(d) determining suitable values of flow rate and temperature for the fluid in the fluid channel to achieve the predetermined temperature difference; and

(e) instructing the thermostatic control valve and the variable speed flow pump to realise the values from step (d).

The method steps may be repeated automatically at predetermined time intervals in order to manage perturbations in the configuration of the pump over time.

The thermal controller may comprise a microprocessor which may be embodied in a computer, which in turn is optionally programmed by computer software which, when installed on the computer, causes it to perform the method steps (a) to (e) mentioned above.

The present invention enables a pump to be subject to an improved level of thermal control. This allows benefits to be achieved during operation of the apparatus in terms of providing optimised running clearances, reducing the occurrence of cold spots in the inlet of the pump, reducing thermal lag in the apparatus and enhancing the likelihood of restart in circumstances where deposits are formed due to cooling.

An example of the present invention will now be described with reference to the accompanying drawings in which:

Figure 1 illustrates a schematic plan cross section of a screw pump of the present invention;

Figure 2 illustrates a plan cross section of a double-ended screw pump of the present invention;

Figure 3 is a flow diagram of a temperature control circuit of the present invention; and

Figure 4 illustrates further detail of the interface between the rotor and the stator of the pump in Figure 2.

Screw pumps are illustrated in Figures 1 and 2. Two rotors 1 are provided within an outer housing 2. The two contra-rotating, intermeshing rotors 1 are positioned such that their central axes lie parallel to one another. The rotors 1 are mounted in the housing 2 via bearings 3. The single ended pump of Figure 1 comprises an inlet stator 4 and an exhaust stator 5, whereas the double ended pump of the example in Figure 2 comprises an inlet stator 4 positioned between two exhaust stators 5.

The housing 2 is provided as a double skinned construction. The internal skin acts as the stator of the pump. A cavity 6 is provided between the skins of the housing 2 such that a cooling fluid, such as water, can be circulated around the stator in order to conduct heat away from the working section of the pump. This cavity 6 encircles the full length of the stator i.e. over the inlet stator 4 as well as the exhaust stators 5. Cooling fluid is circulated through this cavity to draw heat away from the hot surface. By providing the water jacket over the length of the stator, heat generated towards the exhaust end of the rotor can be redistributed to the earlier stages when necessary. This will enable the temperature gradient to be reduced and allow a more uniform temperature to be maintained over the surface of the pump. Consequently, the 'cold spots' found in the prior art can be avoided and condensation of potentially corrosive materials in the rotor inlet are substantially reduced. Furthermore, thermal lag is introduced into the

system due to the presence of a complete water jacket which effectively prevents rapid temperature changes in the stator and rotor surfaces e.g. through wind chill effects.

In some cases, the waste products passing through the pump comprise a waxy or highly viscous substance and deposits are formed on the surfaces of the pump during operation. On shut down of the pump, these deposits cool and may solidify. Where such deposits are located in clearance regions between components, they can cause the pump to seize up. The motor may then provide insufficient torque to overcome this additional friction and cause the rotor to rotate. Additional torque can be applied using a leverage bar inserted into a socket on the shaft, which can then be rotated manually. However such a technique exerts a significant load on the rotor and may cause damage. However, it may not be possible to exert sufficient load to release the mechanism and force the shaft to rotate, under these circumstances it may be necessary to decomission the apparatus and take it out of service either for replacement or repair. An alternative use of the water jacket of the present invention can be implemented in these circumstances where the pump has become seized due to cooling of the rotor. The fluid in the cavity 6 of the housing 2 may be heated to raise the temperature of the stators 5 and the rotors 1. This can enhance the pliability of the residue and may assist in releasing the mechanism.

Figure 3 shows how fluid circuits 11,12 and 15 may be used to control thermal conditions within the pump. The cooling liquid, typically a mixture of water and anti-freeze, is provided in a first closed circuit 11 with a circulation pump 17. A second fluid circuit 12, typically containing water, comprises a second circulation pump 18 and a thermostatic control valve 13. A heat exchange component 14 is provided between these two fluid circuits 11, 12. The valve 13 receives an input signal from a thermal sensor 21 located at the stator and uses this to maintain a suitable flow rate in the second circuit 12 to govern the temperature gradient over the heat exchange component 14. This temperature gradient, in turn, maintains the temperature of the first circuit 11.

The rotor 1 comprises a threaded section 9 and a separate shaft component 8 as illustrated in Figure 2. The threaded section 9 is provided with an internal cooling cavity 7, into which is inserted the body of a separate shaft 8. The body of shaft 8 is fractionally smaller in diameter than the diameter of the cooling cavity 7 within the body of the rotor. Thus a cooling channel is provided, through which a coolant material, typically oil, may be passed. This channel is kept small to encourage the flow speed of the coolant to be as high as possible, in order to enhance the cooling function by maintaining the temperature difference between the rotor and the coolant and transporting heat back to a coolant reservoir. The cooling system inlet and outlet are provided through the shaft component 8.

Returning to Figure 3, it can be seen that the oil is retained in another closed circuit 15. This circuit 15 comprises a thermostatic control valve 16, a circulation pump 19 a filter 20 and a heat exchange component 14. This heat exchange component is in contact with a second cooling circuit 12′, which may be the same circuit 12 as described above. The thermostatic control valve 16 receives an input signal from a second thermal sensor 22 which is located within the vicinity of the exhaust. This second thermal sensor may be located for example on the stator or in the exhaust flow.

By introducing two thermostatic control valves as described, it is possible to control the temperature of the pump rotor relative to the stator temperature. The rotor to stator clearance d (as illustrated in Figure 4) in a screw pump is a function of this difference in temperature between the rotor and the stator. By controlling the temperatures of these components it is possible to control the magnitude of this clearance d. Furthermore, it is this clearance d that determines the level of leakage of process gas between the rotor and the stator, such that the volume of leakage is proportional to d^3 for intermediate, transitional flow as shown in "Modern vacuum practice" by Nigel Harris, McGraw Hill (p231). Since leakage affects the performance of the pump, it follows that the performance of the pump can be optimised by controlling the

temperatures of these components. Furthermore, it is beneficial to be able to maintain clearances d such that any particulate content of the process gas does not form a blockage within these clearances and thus inhibit the free running of the rotor1. Such obstruction can severely affect the performance of the pump through restriction of through flow of the process gas but also through additional torque that must be applied by the motor in order to maintain the appropriate speed of rotation of the rotor.

By providing a temperature control circuit within the rotor it is possible to thermostatically control rotor temperature relative to the stator temperature to optimise rotor/stator clearance d. In its simplest implementation the present invention can be used simply to avoid cold spots and thus eliminate corrosion due to condensation build up as discussed above. In a more sophisticated implementation, input signals can be taken from sensors mounted on each of the stator 5 and the rotor 1 and these signals can be used in a closed loop control system to maintain a set temperature, for example less than 135 °C. This allows a pump using the present invention to safely process materials with a known auto-ignition temperature.

However, as discussed above, the present invention can be used at an even higher level of sophistication to select particular temperatures that will result in a particular clearance d being achieved and maintained. Under normal operation, a dry pump will attain a particular pumping speed determined by clearance between the rotor and the stator. If the inlet pressure to the pump is increased more gas will enter the pump. This additional gas will cause the rotors to cool down with respect to the stator and hence the clearance d between these two components will increase. It follows that, at higher pressures, a significant amount of leakage around the rotor will occur. This is particularly problematic when pumping gas species such as helium, which typically result in low pump speeds and gas throughput being achieved when approaching atmospheric pressures. With the control feature of the present invention it is possible to artificially reduce the clearance d between the rotor and the stator.

Consequently leakage around the rotor may be reduced and the efficiency of the pump can be improved significantly. In the above example, when pumping helium, it is desirable to maintain a small gap to prevent leakage. However, the same pump could be used, in an alternative application, to pump Argon where a larger gap would be required. By providing a pump that can essentially be optimised during operation to function efficiently under varying conditions, a multi-purpose pump is achieved. This functionality can be used to good effect in fields, such as the pharmaceutical or chemical process industries, where a single pump needs to be used for different applications using the same tooling.

The temperature control can be dynamic within a particular process. On start up there will typically be a greater temperature difference since the temperature of the rotor increases at a faster rate than the stator. However, once the pump has reached a steady state this temperature difference will be reduced. By performing the temperature control dynamically, this early difference can be minimised such that the clearance d can be maintained at an approximately steady value. This, in turn, will lead to a more consistent level of pump efficiency.

The present invention is not restricted for use in screw pumps and may readily be applied to other types of pump such as claw pumps or roots pumps.

It is to be understood that the foregoing represents just a few embodiments of the invention, others of which will no doubt occur to the skilled addressee without departing from the true scope of the invention as defined by the claims appended hereto.

Claims

1. A pump comprising:
   at least one rotor;
   a stator; and
   a housing, the housing comprising an inner skin and an outer skin, a first cavity being formed by the inner skin, the rotor being mounted therein and a second cavity being formed between the inner and outer skins of the housing through which a fluid is circulated, in use, wherein, the second cavity extends the length of and encircles the rotor.

2. A pump according to claim 1, wherein the inner skin of the housing acts as the stator, in use.

3. A pump according to claim 1 or claim2, wherein the at least one rotor comprises one inlet portion and two exhaust portions such that the pump is a double-ended pump.

4. A pump according to any preceding claim, further comprising:
   at least one fluid channel located within the rotor and/or the stator; and
   a thermal control means for controlling the temperature of a fluid, when present, in the channel.

5. A pump according to claim 4, wherein the thermal control means comprises:
   a first temperature sensor, located at the stator; and
   a second temperature sensor, located in the vicinity of the exhaust.

6. A pump according to claim 4 or claim 5, wherein the thermal control means further comprises:
   at least one variable speed flow pump;
   at least one thermostatic control valve; and
   at least one heat exchanger.

7. A pump according to any of claims 4 to 6, wherein the thermal control means includes a microprocessor.

8. A pump according to any of the preceding claims, wherein the pump is one of the group of a screw pump, a claw pump and a roots pump.

9. A method for releasing the rotors of a pump that have seized due to the presence of deposits of a substance which has solidified on the internal working surfaces of the pump on cooling, comprising the steps of:

introducing a thermal fluid into a cavity provided within the housing of the pump, the cavity encircling the rotor components;

heating the thermal fluid in the cavity to a predetermined temperature, this temperature being sufficiently high to cause the deposits to be softened; and

applying torque to the rotors of the pump to overcome any remaining impeding force caused by the deposits located on the internal working surfaces of the pump.

10. A method for controlling a clearance between a rotor and stator within a pump according to claim 6 or claim 7, the method comprising the steps of:

(a) recording the temperature of each of the stator and the rotor from the sensors;

(b) calculating the temperature difference between the stator and the rotor;

(c) comparing the temperature difference with a predetermined value;

(d) determining suitable values of flow rate and temperature for the fluid in the fluid channel to achieve the predetermined temperature difference; and

(e) instructing the thermostatic control valve and the variable speed flow pump to realise the values from step (d).

11.A method according to claim 10, wherein the method steps are automatically repeated at predetermined time intervals to manage perturbations in the configuration of the pump over time.

12.A computer program which, when installed on a computer, causes the computer to perform the method of claim 10 or claim 11.

13.A computer readable carrier medium which carries a computer program as claimed in claim 12.

14.A computer readable carrier medium according to claim 13, wherein the medium is selected from; a floppy disk, a CD, a mini-disc or digital tape.

15.A pump apparatus substantially as described herein with reference to the Figures 1 to 4

ABSTRACT

A PUMP

A pump comprising at least one rotor 1, a stator 5 and a housing 2. The housing 2 comprises an inner skin and an outer skin. The rotor is mounted within a cavity that is formed by the inner skin. A second cavity 6 is formed between the inner and outer skins of the housing 2. Fluid is circulated through this second cavity 6 when the pump is in operation. The second cavity 6 extends the length of and encircles the rotor 1.

(Fig.1)

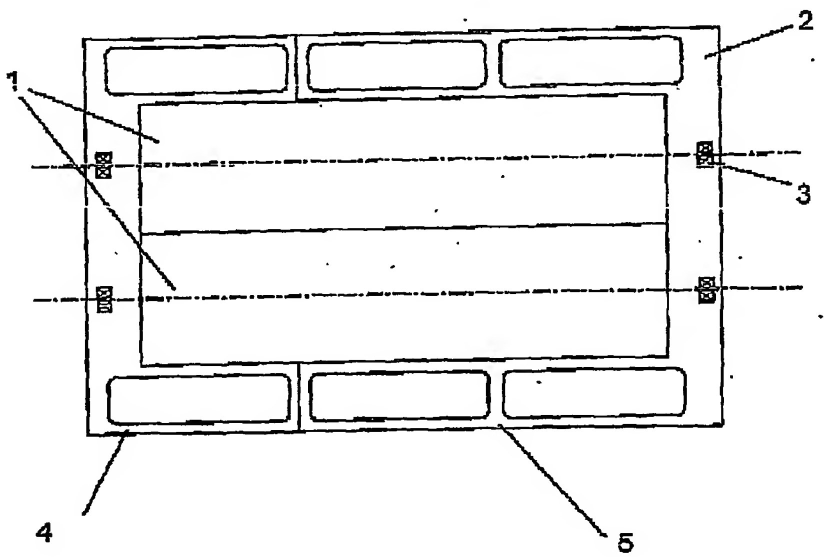

Figure 1

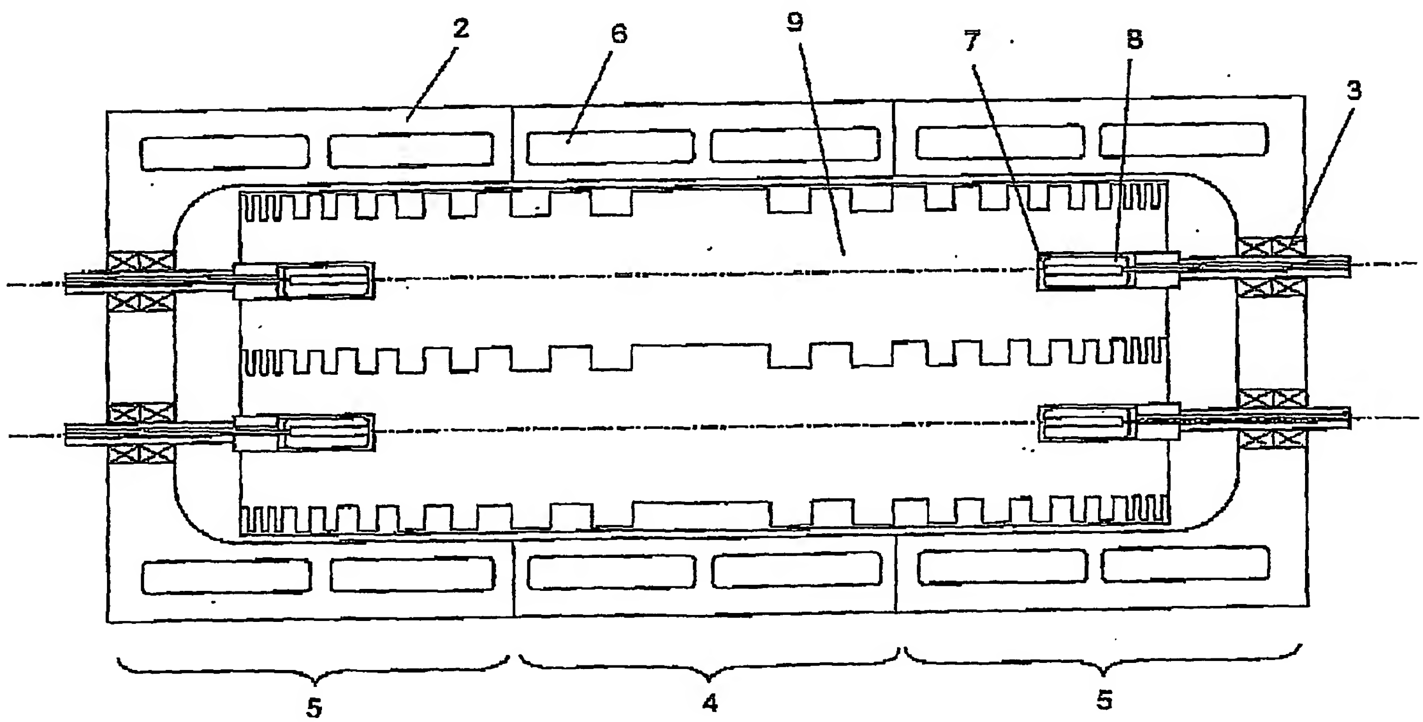

Figure 2

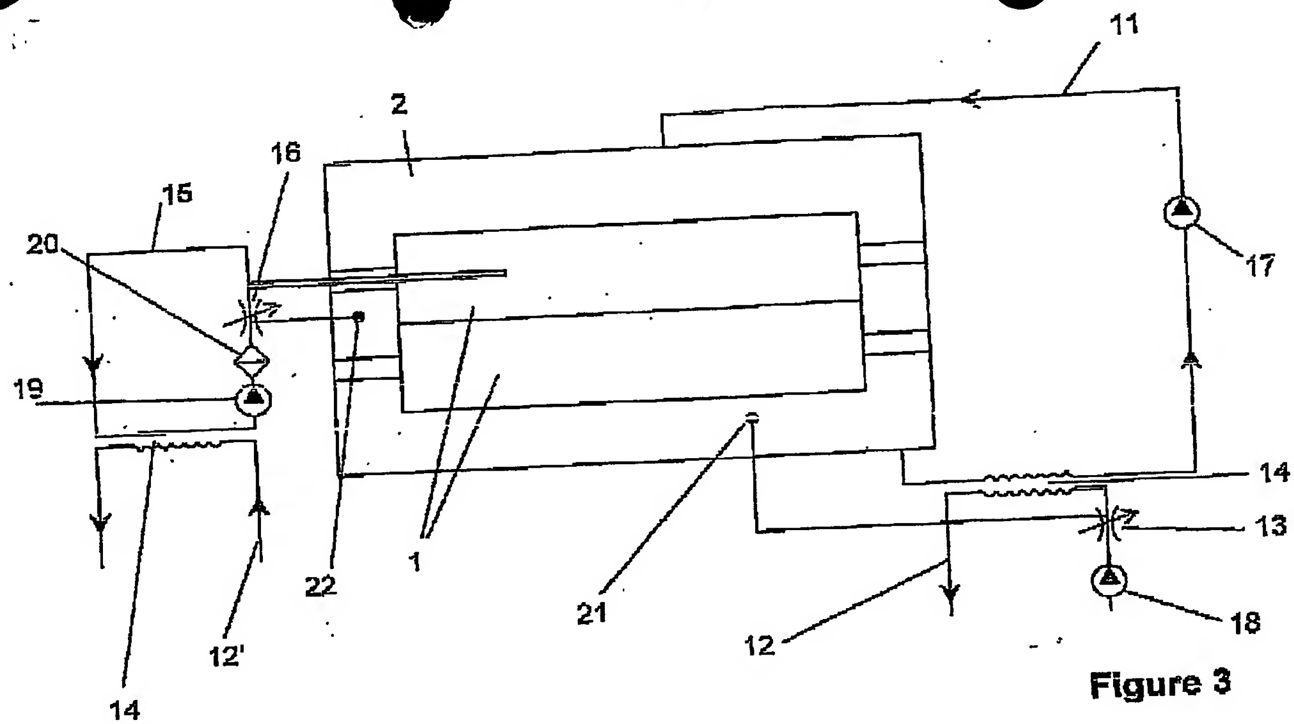

Figure 3

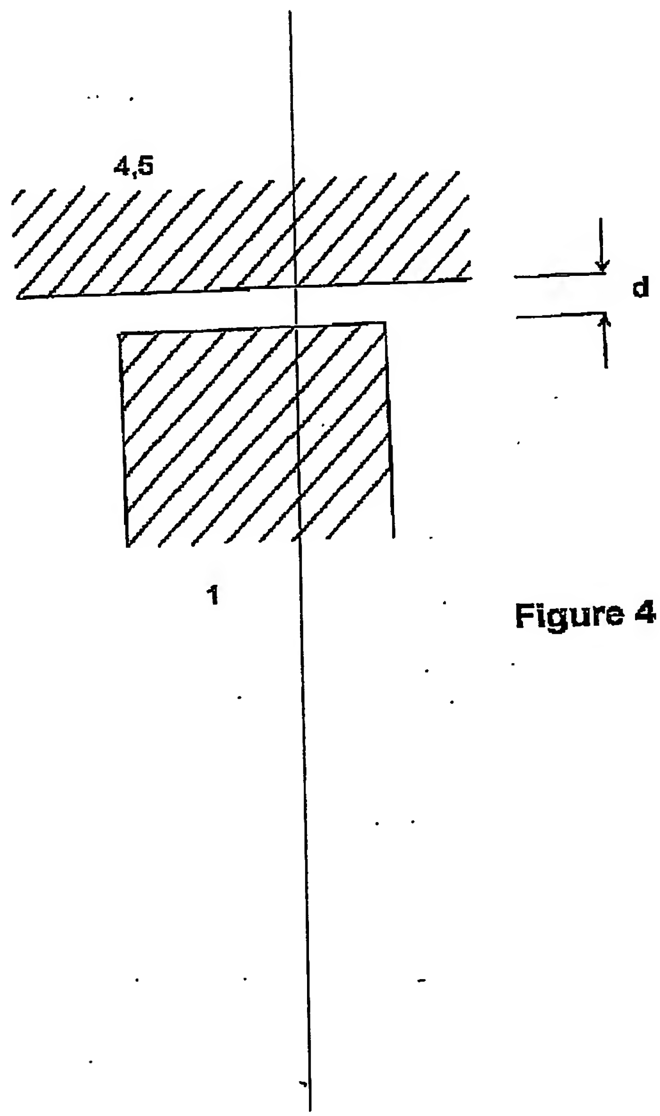

Figure 4

PCT Application
GB0304415